TITLE
Reporting of acute programme variables and exercise descriptors in rehabilitation strength training for tibiofemoral joint soft tissue injury: A systematic review.

AUTHOR
Goff, Anthony J; Page, William S; Clark, Nicholas C.

JOURNAL
Physical therapy in sport : official journal of the Association of Chartered Physiotherapists in Sports Medicine

DATE DEPOSITED
22 November 2018

Title:

Reporting of acute programme variables and exercise descriptors in rehabilitation strength training for tibiofemoral joint soft tissue injury: a systematic review.

Author name and affiliations:

First Author: Anthony J Goff

Health and Social Sciences, Singapore Institute of Technology, 10 Dover Drive, Singapore, 138683

anthony.goff@singaporetech.edu.sg

Second Author: William S Page

Faculty of Sport, Health and Applied Sciences, St Mary's University, Waldegrave Road, Twickenham, TW1 4SX

william.page@stmarys.ac.uk

Third Author and Corresponding Author: Nicholas C Clark

Faculty of Sport, Health and Applied Sciences, St Mary's University, Waldegrave Road, Twickenham, TW1 4SX

nicholas.clark@stmarys.ac.uk

PII: S1466-853X(18)30147-0

DOI: https://doi.org/10.1016/j.ptsp.2018.10.012

Accepted: 20 October 2018

To appear in: Physical Therapy in Sport

To cite this manuscript: Goff, A.J., Page, W.S., Clark, N.C., Reporting of acute programme variables and exercise descriptors in rehabilitation strength training for tibiofemoral joint soft tissue injury: A systematic review, Physical Therapy in Sport (2018), doi: https://doi.org/10.1016/j.ptsp.2018.10.012

Title:

Reporting of acute programme variables and exercise descriptors in rehabilitation strength training for tibiofemoral joint soft tissue injury: a systematic review.

Conflicts of Interest: None

Abstract:

Objective

Strength training acute programme variables (APVs) can impact tibiofemoral joint injury outcomes. Exercise descriptors (EDs; e.g. patient-position) specify configurations within which APVs are applied. Evidence-based practice depends on adequate reporting of APVs and EDs to replicate strength training interventions in clinical practice. This systematic review assessed APV and ED reporting for adults with tibiofemoral joint injury (anterior cruciate ligament (ACL)/posterior cruciate ligament (PCL)/medial collateral ligament (MCL)/lateral collateral ligament (LCL)/meniscus/hyaline cartilage (HC)).

Methods

PRISMA guidelines were followed. Specific key-term combinations were employed and database searches performed. Descriptive/observational/experimental studies were included (2006-2018). Studies needed to report pre-defined APVs or EDs for ≥ 51% of all exercises to be included. Frequency counts were made of studies adequately reporting APVs and EDs.

Results

Sixteen articles were included (ACL=13; meniscus=3). No PCL/MCL/LCL/HC articles were identified. Of nine APVs, five and four were consistently reported by the majority of ACL (≥7) and meniscal (≥2) studies, respectively. Of eight EDs, four were consistently reported by the majority of both ACL (≥8) and meniscal (≥2) studies.

Conclusion

Many APVs and EDs were not adequately reported. Future studies should better document APVs and EDs for higher standards of intervention reporting and enhanced translation of research to clinical practice.

1. Introduction

The knee joint is one of the largest and most commonly injured joints in the body, accounting for 15-18% of musculoskeletal injuries per year [1, 2]. Tibiofemoral joint (TFJ) injuries include anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), medial collateral ligament (MCL), lateral collateral ligament (LCL), meniscus, hyaline cartilage, and proximal tibia and distal femur bone injuries, together yielding a prevalence of 77-90% of all knee injuries [3, 4]. Such injuries impact healthcare systems due to frequent need for acute medical/surgical intervention [3-5], the financial cost of such interventions often being the highest of all sports injuries [5, 6]. In Europe, healthcare costs of acute cruciate ligament injuries exceed those of other TFJ injuries [5]. In the United States, healthcare costs of ACL surgery are also some of the highest of all TFJ injuries, a nationwide annual cost estimate exceeding one billion dollars [7, 8]. Further, TFJ injury rehabilitation can last many months [9], and approximately 50% of patients experiencing ACL and/or meniscus injury can present with further healthcare needs 10-20 years later because of symptomatic knee osteoarthritis [10, 11]. Therefore, TFJ injuries can represent a major burden for healthcare systems due to short- and long-term financial costs.

Common impairments following TFJ injury include pain [12, 13], effusion [14, 15], muscle weakness [16-18], and decreased bone mineral density [19-21]. Activity limitations, such as a decreased ability to perform gait and activities of daily living, are commonly present after TFJ injury [22, 23]. Restricted participation in society, such as a decreased ability to perform occupational tasks and sporting activities, can typically also be observed after TFJ injury [24, 25]. Consequently, TFJ injuries can result in widespread effects across individuals' day-to-day lives.

Rehabilitation strength training (hereafter, 'strength training') is a critical component of rehabilitation for individuals with TFJ injury [26, 27], being able to modify the magnitude of an inflammatory process [28] and resolve specific post-injury impairments such as muscle weakness and reduced bone mineral density [29, 30]. Further, knee muscle strength is positively correlated with the performance of functional tasks [31, 32] and is associated with more favourable patient-reported outcomes after TFJ injury and surgery [33-35]. Strength training after TFJ injury is, therefore, clinically important for resolving impairments, mitigating activity limitations, and facilitating injured individuals' return to participation in society.

A safe and effective strength training programme after TFJ injury and surgery should be designed based on sound scientific and clinical principles [27]; this requires specific acute programme variables (APVs) (*Table 1*) to be appropriately combined in order to elicit and optimise desired physiological and physical responses in the body [36-40]. For example: from a safety perspective isometric muscle actions are often performed in rehabilitation at one point in a range-of-motion for some form of short-term joint protection [41] because anisometric (dynamic) muscle actions may initially overload healing tissues; from an effectiveness perspective APVs can be manipulated to specifically enhance knee extension isometric relative strength [42], to enhance cortical bone characteristics [43], and to modify TFJ stiffness [44]. Sufficient exercise descriptors (EDs) (*Table 1)* are required for clinicians to understand exercise configurations. For example: from a safety perspective some loading methods are consistent, almost insusceptible to material fatigue, and preferable if highly controlled rehabilitation loads are desired (e.g. fixed mass of a metal ankle weight), whereas others are not (e.g. elastic resistance) [45, 46]; from an effectiveness perspective double-leg exercises can result in patients 'cheating' with the uninjured leg and avoiding clinically appropriate loading of the injured leg [47]. Failure to report all clinically important details that include APVs and EDs can, therefore, result in potentially unsafe and low effectiveness strength training programmes when clinicians attempt to translate research findings to their day-to-day clinical practice [36, 40, 48, 49]. Further, inadequate reporting of APVs and EDs could likely even impact on the initial uptake of research findings by responsible clinicians because there would not be sufficient information as a starting point for administering an intervention for which said clinicians would legally be liable.

*Table 1. Acute Programme Variables and Exercise Descriptors for Tibiofemoral Joint Rehabilitation Strength Training**

Acute Programme Variables (APVs)	**Exercise Descriptors (EDs)**
Exercise order	Compound or isolated exercise
Type of muscle action (isometric, anisometric)	Patient position
Number of sets	Single- or double-leg exercise
Number of repetitions	Joint angle/arc-of-motion
Magnitude of load	Loading method
Velocity of movement	Total duration of programme
Between-set rest period	Unsupervised/supervised exercise
Weekly frequency of sessions	Progression criteria for exercise**
Number of rest days between sessions	

*Modified from: Augustsson [36], Kraemer and Koziris [40], and Toigo and Boutellier [37]. **Refers to objective measurement-based progression criteria (i.e. goal = e.g. pre-defined number of repetitions per set) versus time-based progression criteria.

For clinicians to adhere to evidence-based practice principles and replicate strength training interventions in day-to-day clinical practice depends on whether APVs and EDs are adequately reported in the scientific literature [48-50]. One recent systematic review [36] investigated reporting of APVs and EDs in ACL rehabilitation between 1983 and 2012; the main finding was that of the six studies that fulfilled the review's inclusion criteria only two "arguably" reported sufficient APV information, whilst the other four did not provide APV information such as frequency or intensity of training sessions. Although the systematic review [36] is useful for understanding some aspects of the reporting of APVs in knee strength training, relative to the APVs and EDs listed in Table 1, the review did not examine the reporting of other clinically important APVs and EDs (e.g. arc-of-motion, single- or double-leg exercise). The present authors have been unable to identify any systematic reviews specifically on reporting of APVs and EDs in strength training for individuals with PCL, MCL, LCL, meniscal, or hyaline cartilage injury. As such, it is unclear whether reporting of APVs and EDs in scientific literature investigating strength training for individuals with TFJ soft tissue injury can be considered adequate for translation to clinical practice. Because of the safety and effectiveness considerations outlined previously, and because of the fundamental reporting detail needed for the responsible translation of research to clinical practice also outlined previously, the purpose of this systematic review was to determine the extent to which APVs and EDs are adequately reported in studies of adults with TFJ soft tissue injury. We hypothesized that strength training APVs and EDs would not be adequately reported by the majority of included studies for ACL, PCL, MCL, LCL, meniscal, or hyaline cartilage injury. This systematic review will differ from recent previous work [36] in that it will focus on more than one type of TFJ injury, assess a greater number of

APVs and EDs, and encompass more recent research. The anticipated significance of this review is that it will yield important information that helps focus enhanced reporting of TFJ strength training interventions in future research.

2. Methods

This review was registered on the International Prospective Register of Systematic Reviews (PROSPERO: ID = CRD42016042315)[51], and followed all relevant items in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [52, 53].

2.1 Search Strategy

Comprehensive electronic searches were performed on 14th March 2018 using two medical databases (PubMed, MEDLINE), two allied health databases (PEDro, CINAHL), and one sports database (SportDiscuss) using specific combinations of pre-defined key terms (*Table 2*). We did not use Medical Subject Heading (MeSH) terms because research studies are listed in PubMed long before being indexed with MeSH terms; this means that placing emphasis on the use of MeSH terms can result in the most recently listed research studies not being captured and missed [54]. Piloting of our specific combinations of pre-defined key terms and study selection process was performed and found to be effective.

*Table 2. Pre-defined Key Terms and Key Term Combinations for Literature Search*es

Item 1	With/without Item 2	And Item 3	And Item 4
Anterior Cruciate Ligament Posterior Cruciate Ligament Medial Collateral Ligament Lateral Collateral Ligament Meniscus Hyaline Cartilage Cartilage	Deficient Conservative Reconstruction Repair	Rehabilitation	Strength training Resistance training Weight training

This review only considered TFJ soft tissue injury studies involving adults (age ≥ 18 years) and that were of descriptive (case series), analytic-observational (cohort, case-control), and analytic-experimental (randomised controlled trial) design [55, 56]. Tibiofemoral joint soft tissue injury was defined as any injury that involved the ACL, PCL, MCL, LCL, medial/lateral meniscus, and hyaline cartilage. Included studies employed strength training methods that used a fixed mass as the means of providing exercise resistance (e.g. ankle-weight, plate-loaded resistance training machine, free-weight, body-weight). Studies were excluded from this review if participants were age < 18 years, had sustained a TFJ bone injury, had a patellofemoral joint injury, or had patellar tendinopathy. Studies were also excluded if they primarily used elastic, hydraulic, or pneumatic exercise resistance (‘primarily used’ was defined as ≥ 51% of all exercises), or used mixed-modality interventions (e.g. strength training + electrical stimulation).

Only articles published from 1st January 2006 onwards were considered because it was in 2006 that Toigo and Boutellier [37] called for enhanced strength training programme reporting with uninjured individuals. However, recognizing the call from Toigo and Boutellier [37] referred to uninjured individuals, we were only interested in APVs and EDs we considered most important in clinical practice

(Table 1) and as classically defined and prioritised in previous clinically-focused publications [36, 40]. We also only considered articles published from 1st January 2006 onwards because, as practicing clinicians with >37 years of collective clinical experience, and given the ongoing year-to-year rapid evolution of surgical techniques and post-injury/post-surgery restrictions, we deemed that research published no longer than approximately 10 years ago was of most interest relative to the design and application of present day knee strength training programmes.

Following database searches, duplicates were removed prior to two of the research team members independently screening abstracts to ascertain eligibility for inclusion in the review. Following abstract screening, only full-text English language studies were obtained for further assessment of eligibility through a full text review.

2.2 Data extraction and synthesis

Following eligibility assessment, data were extracted and entered into customized Microsoft Excel spreadsheets (Appendices). Data included study characteristics (e.g. study design, participant demographics, surgery occurrence), exercise names, and the APVs and EDs listed in Table 1. The presence or absence of an APV or ED was coded as binary data (1 = present; 0 = absent) for each exercise. When a study with ambiguous APVs/EDs was identified, the two primary reviewers met to discuss the study contents and achieve agreement on its eligibility status. If the meeting failed to resolve any ambiguity, the third member of the research team facilitated a consensus regarding final eligibility for inclusion in this review. This review focused simply on the extent to which APVs and EDs were reported by eligible studies. This review did not focus on the outcome (efficacy, effectiveness) of any intervention. Therefore, risk of bias within studies was not relevant to the purpose of this review and a quality assessment of included studies was not performed.

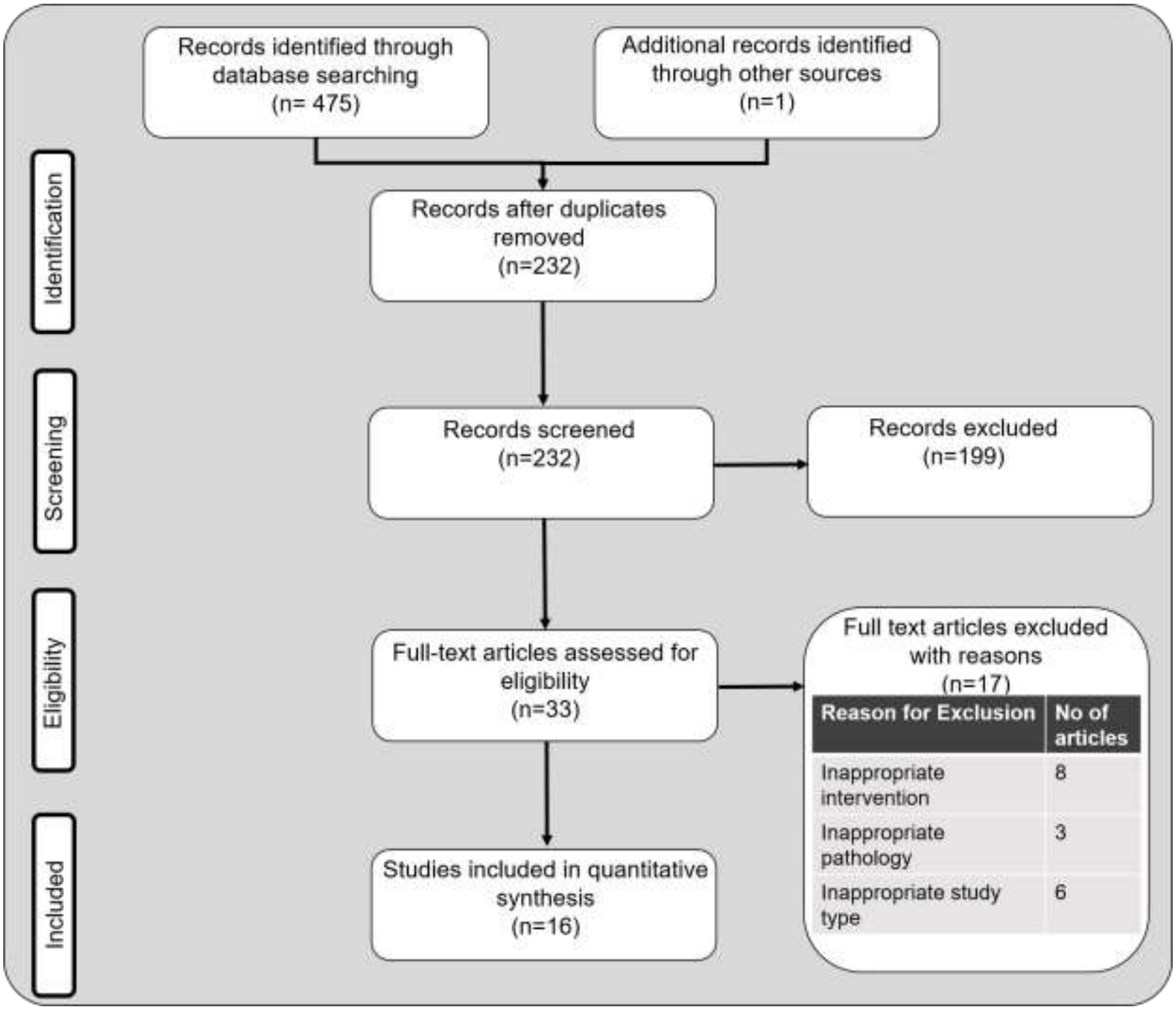
2.3 Data Analysis

For all included studies, frequency counts were made for the presence of APVs and EDs. Because different studies contain different numbers of exercises, we defined ‘adequately reported’ as where an individual study reported an APV and/or ED for ≥ 51% of all of its exercises (i.e. the majority of all exercises). Proportions were then calculated to describe the percentage of studies that reported APVs and/or EDs: APV proportion (%) = (number of studies with APV present ÷ total number of studies included in review) × 100; ED proportion (%) = (number of studies with ED present ÷ total number of studies included in review) × 100.

3. Results

Details of the search results and study identification process are presented in Figure 1. Full details and characteristics of the 16 studies included for final data synthesis can be found in the Appendices.

Figure 1. PRISMA Flowchart



Of the 16 studies, 13 (81%) pertained to ACL injury [44, 57-68], the remaining three (19%) pertaining to meniscal injury [69-71]. No eligible articles were found for PCL, MCL, LCL, or hyaline cartilage injury.

Of the 13 ACL studies, 12 were randomised controlled trials and one was a single cohort study. Mean participant age ranged from 22 to 35 years, with nine studies including both male and female participants. Nine studies included an ACL-reconstruction sample, four studies included an ACL-deficient sample. Acute programme variable and ED frequency counts for the ACL studies are presented in *Figure 2* and *Figure 3*. Of the 13 included studies, there was great variation in the percentage of studies adequately reporting specific APVs (range 0-92%): exercise order 0%, type of muscle action (isometric, anisometric) 85%, number of sets 85%, number of repetitions 92%, magnitude of load 54%, velocity of movement 8%, between-set rest period 31%, weekly frequency of sessions 85%, number of rest days between sessions 0%. There was also great variation in the percentage of studies adequately reporting specific EDs (range 15-100%): compound or isolated exercise 92%, patient position 54%, single- or double-leg exercise 62%, joint angle/arc-of-motion 15%, loading method 38%, total duration of programme 100%, unsupervised/supervised exercise 85%, progression criteria 31%.

Of all APVs, only 5/9 (56%) were adequately reported (type of muscle action, number of sets, number of repetitions, magnitude of load, weekly frequency of sessions). Of all EDs, only 4/8 (50%) were adequately reported (compound/isolated exercise, single-/double-leg exercise, total duration of programme, unsupervised/supervised exercise).

Figure 2. Acute Programme Variable (APV) Frequency Count for Anterior Cruciate Ligament Studies

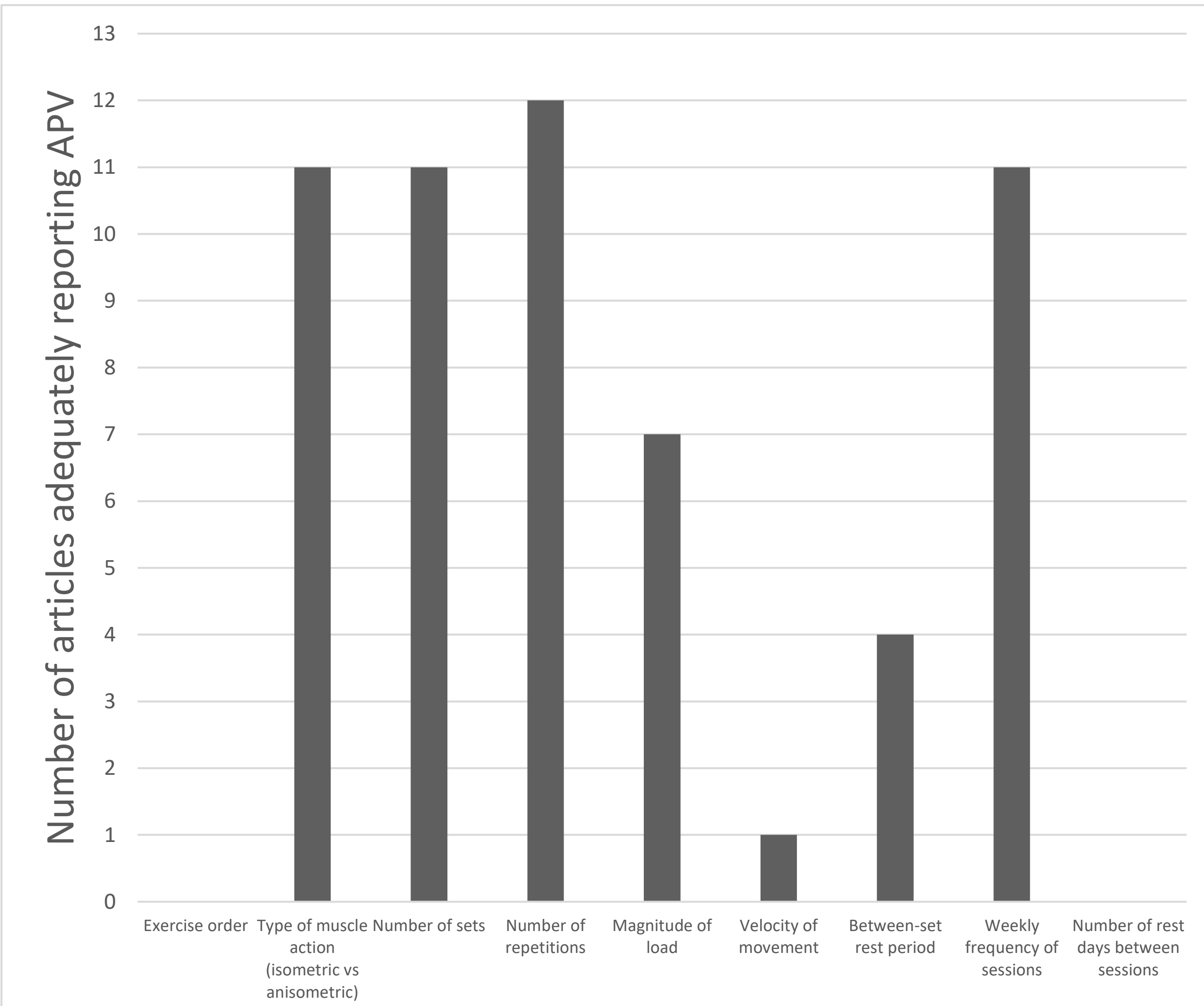
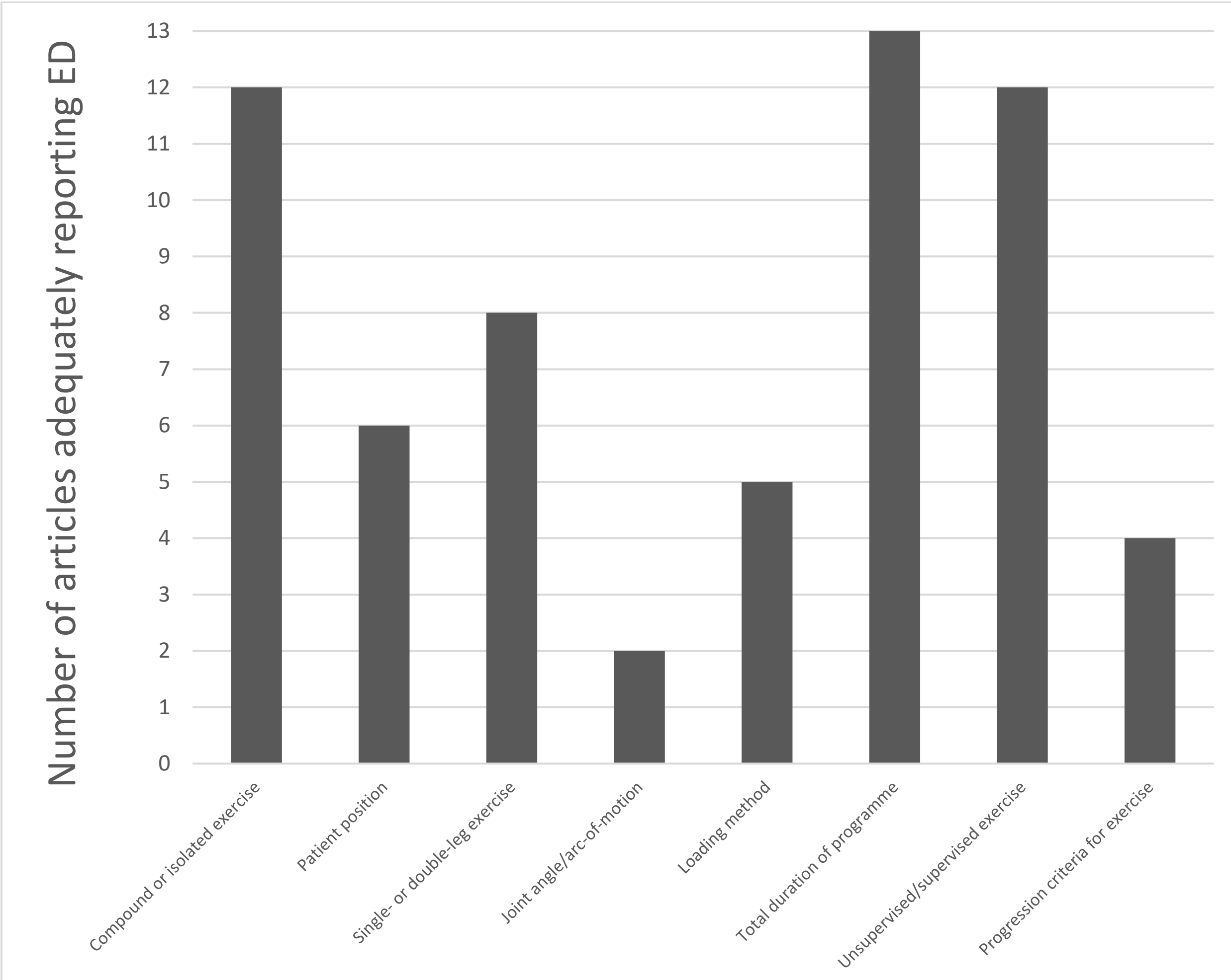


Figure 3. Exercise Descriptor (ED) Frequency Count for Anterior Cruciate Ligament Studies



Of the three meniscus studies, two were randomised controlled trials and one was a single cohort study. Mean participant age ranged from 34 to 55 years, with all studies including both male and female participants. Two studies included post-meniscectomy samples, one study a meniscus diagnostic arthroscopy sample. Acute programme variable and ED frequency counts for the meniscus studies are presented in *Figure 4* and *Figure 5*. Of the three included studies, there was great variation in the percentage of studies adequately reporting specific APVs (range 0-100%): exercise order 0%, type of muscle action (isometric, anisometric) 67%, number of sets 67%, number of repetitions 67%, magnitude of load 33%, velocity of movement 0%, between-set rest period 0%, weekly frequency of sessions 100%, number of rest days between sessions 0%. There was also great variation in the percentage of studies adequately reporting specific EDs (range 33-100%): compound or isolated exercise 33%, patient position 33%, single- or double-leg exercise 33%, joint angle/arc-of-motion 33%, loading method 67%, total duration of programme 100%, unsupervised/supervised exercise 100%, progression criteria 67%.

Of all APVs, only 4/9 (44%) were adequately reported (type of muscle action, number of sets, number of repetitions, weekly frequency of sessions). Of all EDs, only 4/8 (50%) were adequately reported (loading method, total duration of programme, unsupervised/supervised exercise, progression criteria).

Figure 4. Acute Programme Variable (APV) Frequency Count for Meniscus Studies

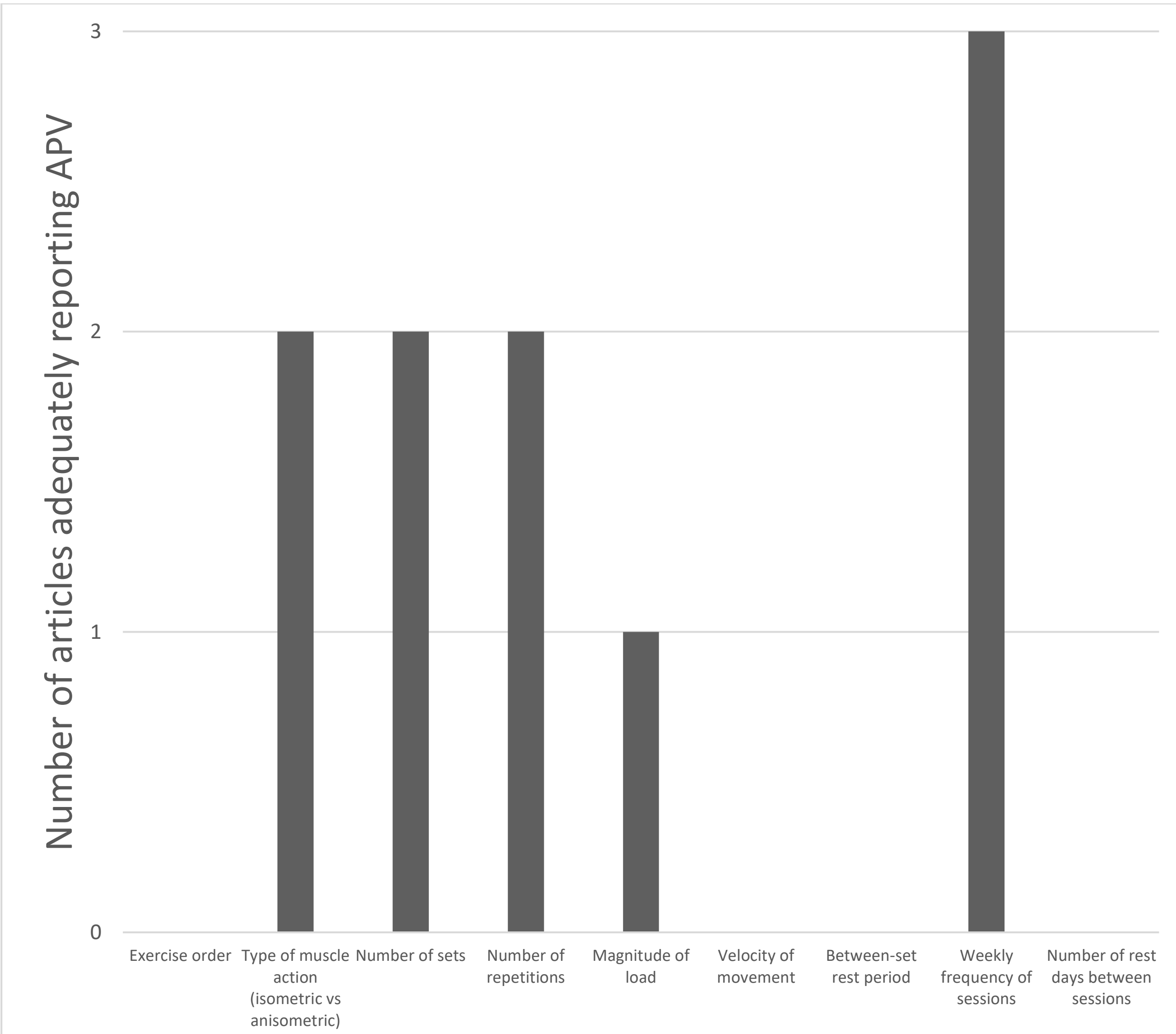
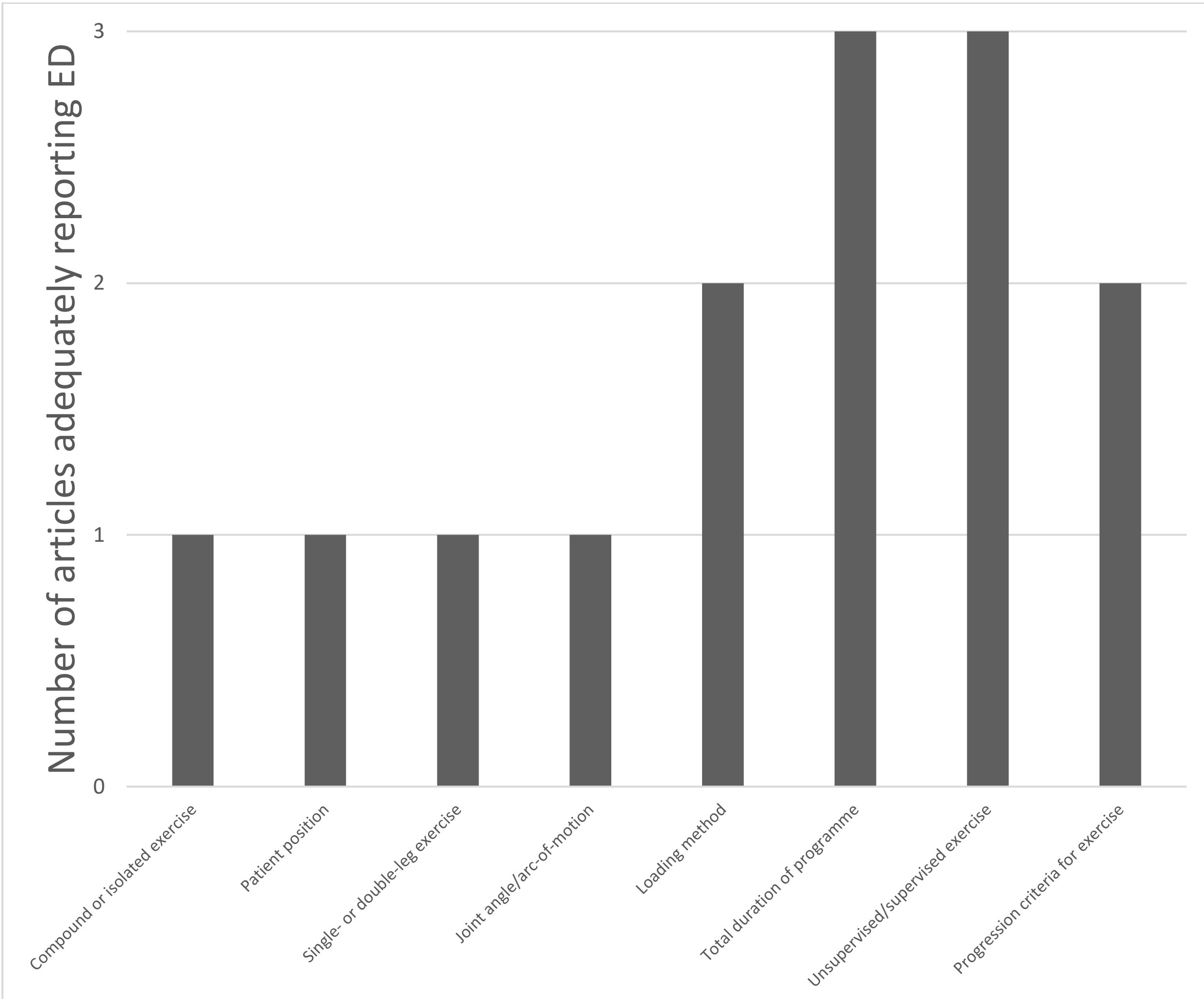


Figure 5. Exercise Descriptor (ED) Frequency Count for Meniscus Studies



Discussion

The purpose of this systematic review was to determine the extent to which strength training APVs and EDs are reported in studies of adults with TFJ soft tissue injury. We hypothesized that strength training APVs and EDs would not be adequately reported by the majority of included studies for ACL, PCL, MCL, LCL, meniscal, or hyaline cartilage injury. The results partially support our hypothesis: APVs were adequately reported by the majority of ACL studies, but not for meniscal studies. Additionally, EDs were not adequately reported by the majority of ACL or meniscal studies. No eligible PCL, MCL, LCL, or hyaline cartilage studies were identified for inclusion in this systematic review. Although the majority of APVs were adequately reported by the included ACL studies, a large proportion of APVs (4/9, 44%) were not adequately reported.

This systematic review differed from recent previous reviews in that it focused on more than one type of TFJ injury, assessed a greater number of APVs and EDs, and encompassed more recent research. Relative to ACL injury, our findings are consistent with the systematic review by Augustsson [36] who identified unsatisfactory reporting of APVs and EDs in strength training programmes. In the previous review by Augustsson [36], only six studies were included, whereas in the current review 13 studies were included. Poor and inconsistent reporting of APVs and EDs in strength training has also been highlighted for other knee conditions including patellofemoral pain [50] and knee osteoarthritis [72]. In a systematic review including 38 patellofemoral pain studies, Holden et al [50] identified that no single study provided complete strength training programme information, with number of rest days between sessions being one of the least reported variables. In another systematic review of 34 knee osteoarthritis studies, Minshull and Gleeson [72] demonstrated that APVs were inconsistently applied and insufficiently reported across all studies, with between-set rest periods being one of the least reported variables. The present work, alongside the work of Augustsson [36], Holden et al [50] and Minshull and Gleeson [72], highlights the need for more consistent and robust methods of reporting strength training APVs and EDs in order to facilitate effective knowledge translation and implementation of evidence-based practice knee rehabilitation.

The vast majority of studies in this review were strength training interventions for ACL injury as opposed to other TFJ soft tissue injuries, which is likely a reflection of researchers' preferred foci worldwide rather than the incidence of other TFJ injuries. Because the majority of studies focused on ACL injuries, this highlights a severe lack of scientific literature for the rehabilitation for other TFJ soft tissue injuries (e.g. PCL, MCL, LCL, hyaline cartilage), despite strength training being considered a critical component for mitigating impairments and activity limitations, and facilitating an individual's participation in society [73].

Exercise order impacts both acute physiological responses and chronic adaptations to strength training [39]. However, no study identified in this review explicitly stated the order in which exercises were performed. The potential variation in order of strength training exercises in rehabilitation may lead to sub-optimal acute physiological responses as well as excessive fatigue which could impact upon more short- and medium-term clinical outcomes (e.g. activity capability).

The selection of either isometric or anisometric muscle action can be important as they can each elicit different physiological responses [74-77]. Further, isometric muscle actions are often performed in rehabilitation at one or more points in a range-of-motion for some form of short-term joint protection [41] and, therefore, may not result in training adaptations throughout the range-of-motion [78]. For identified ACL and meniscal studies, the type of muscle action was generally adequately reported.

Given that progressive overload is one of the cornerstone principles of strength training, the volume load of each exercise can have a direct impact upon physiological responses, chronic adaptations, and overall clinical outcomes during TFJ injury rehabilitation [38, 40, 79, 80]. Volume load is typically determined by calculating the total number of repetitions (sets × repetitions) and multiplying this by the magnitude of load (e.g. kilograms (kg)) [79, 81, 82]. The magnitude of load represents the intensity component of progressive overload, and can be calculated/reported an absolute load (e.g. 5kg) or a relative load (e.g. percentage of one repetition maximum (%1RM)) [79, 83]. Whilst sets, repetitions, and load were adequately reported across the majority of ACL studies, only sets and repetitions were adequately reported across meniscus studies with the magnitude of load and relative intensity being frequently omitted. Therefore, based on studies identified in this systematic review, volume load and average intensity cannot be replicated in clinical practice for individuals with meniscus injury.

The velocity at which anisometric muscle actions occur within a repetition can also be important when applying the specificity principle of resistance training [82, 84-86]. For example, in the latter stages of rehabilitation programmes, clinicians may wish to select exercises and APVs to target maximal power gains, for which lower velocity (slower) movements are ineffective [87]. The velocity of a repetition cycle will also impact the length of time taken to perform each set of an exercise and thus affect the overall 'time under tension', another measure of strength training volume which can impact physiological responses and fatigue levels [37, 88-90]. This systematic review identified only one ACL article [91] whereby velocity was adequately reported and total time under tension could have been calculated.

Muscle atrophy and weakness are common impairments following TFJ injury [16, 17, 35, 92] and strength training exercises are often given to elicit muscle hypertrophy and increase muscle strength [29, 42, 93]. Manipulation of the between-set rest period has been shown to impact physiological responses involved with hypertrophy in uninjured adults [94, 95] and, therefore, should be an important APV for therapists to consider when designing TFJ injury strength training rehabilitation programmes to mitigate impairments such as muscle atrophy and loss of muscle strength.

Weekly frequency of sessions and number of rest days between sessions are known to impact muscle hypertrophy and levels of neuromuscular fatigue in uninjured adults [80, 96]. This review found that whilst weekly frequency of sessions were adequately reported across both ACL and meniscal studies, rest days between sessions were often not. Clinically, rest days between sessions are important because too few could result in inadequate tissue recovery from training loads and exceeding the TFJ envelope of function at a set point-in-time [97], and too many could result in sub-optimal hypertrophic gains [80, 96].

Half of EDs (patient position, joint angle/arc of motion, loading method, progression criteria) were not adequately reported by the majority of ACL studies. Additionally, half of EDs (compound or isolated, patient position, single or double legged, joint angle/arc of motion) were not adequately reported for meniscus studies. Clinically, EDs are critical components of strength training because they can affect forces acting across the TFJ in a population that possesses compromised knee anatomy and joint stability [98-100]. The omission of EDs can raise potential safety concerns with regards to, for example, a patient attempting a full-range single-leg squat vs a partial double-leg squat at an inappropriate time in rehabilitation [101].

Strength training programmes following TFJ injury are often progressed in a time-based or objective measurement-based manner [71, 102]. A method to help clinicians decide when to progress an individual's rehabilitation is necessary for both patient safety and continuous improvement [27, 102]. The problem with time-based progression criteria is that individuals can have profound differences in physiological and biochemical characteristics and heal at different rates [27]. Thus, objective measurement-based progression criteria (i.e. goals) are preferred, whereby a patient must achieve a measurable criterion (goal) before an exercise is progressed to a more challenging version [27, 102]. Most of the ACL and meniscus studies presented time-based progression of exercises versus objective measurement-based progression. Of the ACL and meniscus studies that did mention some form of objective measurement-based progression criterion, all were vague with regards to how to then progress exercises to more challenging versions beyond said criterion. A more detailed and standardized format for reporting measurement-based progression criteria, and the methods for progression beyond said criteria, is desirable for TFJ strength training programmes.

The Consensus on Exercise Reporting Template (CERT) offers a standardised method for reporting exercise interventions [49]. We did not use this template in the present review for two reasons: 1. the CERT study [49] was published just after the present review had been registered on PROSPERO [51]; 2. the CERT focuses on clinical trials, whereas the present review planned to encompass a wider range of study designs. The Template for Intervention Description and Replication (TIDieR) also offers a standardised method for reporting interventions [103]. We also did not use this template for two reasons: 1. the emphasis of the TIDieR [103] is also on clinical trials and, again, the present review planned to encompass a wider range of study designs; 2. the TIDieR is a general tool intended for application across different types of intervention including drug treatments and, therefore, is not specific to strength training contexts. As for other recent systematic reviews [50], we did not use other intervention reporting templates because the present review commenced before they were published or such templates are not specific to reporting of strength training APVs and EDs for individuals with TFJ soft tissue injury. As recently proposed by Holden et al [50], future research should consider combining general exercise intervention reporting recommendations offered by the CERT [49] or TIDieR [103] checklists with specific strength training reporting recommendations.

We applied date and language restrictions within our search strategy. Such restrictions clearly exclude earlier studies and publications in other languages. Future systematic reviews could search different timeframes and other language databases to identify other worldwide works on the extent to which strength training APVs and EDs are reported in studies of adults with TFJ soft tissue injury. It could be argued that the 51% threshold for APVs and EDs to be defined as 'adequately reported' should have been higher to facilitate greater translation of EBP. The 51% threshold does, however, serve the purpose of reflecting a majority perspective. Future research can consider whether a higher percentage threshold is appropriate for operationally defining the term 'adequately reported'. This review solely looked at whether strength training APVs and EDs were adequately reported in TFJ rehabilitation studies and did not perform a quality assessment of studies or assess the extent to which APVs are reported against treatment outcomes. Future research should examine whether the extent of strength training APV and ED reporting does, in fact, influence TFJ soft tissue injury injury clinical outcomes.

4. Conclusion

Strength training APVs and EDs are generally not adequately reported in recent studies of adults with TFJ soft tissue injury. The inadequate reporting of APVs in studies of adults with TFJ soft tissue injury threatens the translation of research to clinical practice and the performance of evidence-based exercises due to readers' attempts to interpolate omitted strength training information. The altered performance of TFJ injury strength training programmes could lead to wide variation in individuals' physiological responses and overall clinical outcomes. The significance of this review is that it identifies future studies for rehabilitation of adults with TFJ soft tissue injury should document thorough and detailed strength training APVs and EDs to encourage higher standards of intervention reporting, facilitate better translation of research to clinical practice, and potentially enhance patient-relevant outcomes.

References

1. Ekstrand, J., M. Hagglund, and M. Walden, *Injury incidence and injury patterns in professional football: the UEFA injury study.* Br J Sports Med, 2011. **45**(7): p. 553-8.
2. Swenson, D.M., et al., *Epidemiology of U.S. high school sports-related ligamentous ankle injuries, 2005/06-2010/11.* Clin J Sport Med, 2013. **23**(3): p. 190-6.
3. Dehaven, K.E., *Diagnosis of acute knee injuries with hemarthrosis.* American Journal of Sports Medicine, 1980. **8**(1): p. 9-14.
4. Sarimo, J., et al., *Acute traumatic hemarthrosis of the knee. Is routine arthroscopic examination necessary? A study of 320 consecutive patients.* Scandinavian Journal of Surgery, 2002. **91**(4): p. 361-364.
5. de Loës, M., L. Dahlstedt, and R. Thomée, *A 7-year study on risks and costs of knee injuries in male and female youth participants in 12 sports.* Scand J Med Sci Sports, 2000. **10**(2): p. 90.
6. Cumps, E., et al., *Injury rate and socioeconomic costs resulting from sports injuries in Flanders: data derived from sports insurance statistics 2003.* Br J Sports Med, 2008. **42**(9): p. 767-772.
7. Joseph, A.M., et al., *A multisport epidemiologic comparison of anterior cruciate ligament injuries in high school athletics.* Journal of Athletic Training, 2013. **48**(6): p. 810-817.
8. Silvers, H.J. and B.R. Mandelbaum, *Prevention of anterior cruciate ligament injury in the female athlete.* British Journal of Sports Medicine, 2007. **41**(Suppl 1): p. i52-i59.
9. Risberg, M.A., M. Lewek, and L. Snyder-Mackler, *A systematic review of evidence for anterior cruciate ligament rehabilitation: how much and what type?* Physical Therapy in Sport 2004 Aug;5(3):125-145, 2004.
10. Lohmander, L.S., et al., *The long-term consequence of anterior cruciate ligament and meniscus injuries: osteoarthritis.* The American journal of sports medicine, 2007. **35**(10): p. 1756-1769.
11. Øiestad, B.E., et al., *Knee osteoarthritis after anterior cruciate ligament injury.* Am J Sports Med, 2009. **37**(7): p. 1434-1443.
12. Muller, B., et al., *Defining Thresholds for the Patient Acceptable Symptom State for the IKDC Subjective Knee Form and KOOS for Patients Who Underwent ACL Reconstruction.* Am J Sports Med, 2016. **44**(11): p. 2820-2826.
13. Fox, A.J., et al., *The human meniscus: a review of anatomy, function, injury, and advances in treatment.* Clin Anat, 2015. **28**(2): p. 269-87.
14. Olsson, O., et al., *Epidemiology of intra- and peri-articular structural injuries in traumatic knee joint hemarthrosis - data from 1145 consecutive knees with subacute MRI.* Osteoarthritis Cartilage, 2016. **24**(11): p. 1890-1897.
15. Pezeshki, S., et al., *Association of the type of trauma, occurrence of bone bruise, fracture and joint effusion with the injury to the menisci and ligaments in MRI of knee trauma.* Muscles Ligaments Tendons J, 2016. **6**(1): p. 161-6.
16. Thomas, A.C., et al., *Muscle atrophy contributes to quadriceps weakness after anterior cruciate ligament reconstruction.* J Sci Med Sport, 2016. **19**(1): p. 7-11.
17. Hart, J.M., et al., *Quadriceps activation following knee injuries: a systematic review.* J Athl Train, 2010. **45**(1): p. 87-97.
18. Sturnieks, D.L., et al., *Knee strength and knee adduction moments following arthroscopic partial meniscectomy.* Med Sci Sports Exerc, 2008. **40**(6): p. 991-7.
19. van Meer, B.L., et al., *Bone mineral density changes in the knee following anterior cruciate ligament rupture.* Osteoarthritis Cartilage, 2014. **22**(1): p. 154-61.
20. Lui, P.P., et al., *A randomized controlled trial comparing bone mineral density changes of three different ACL reconstruction techniques.* Knee, 2012. **19**(6): p. 779-85.
21. Bayar, A., et al., *Regional bone density changes in anterior cruciate ligament deficient knees: a DEXA study.* Knee, 2008. **15**(5): p. 373-7.
22. Thoma, L.M., et al., *Differential knee joint loading patterns during gait for individuals with tibiofemoral and patellofemoral articular cartilage defects in the knee.* Osteoarthritis Cartilage, 2017. **25**(7): p. 1046-1054.
23. Sigward, S.M., P. Lin, and K. Pratt, *Knee loading asymmetries during gait and running in early rehabilitation following anterior cruciate ligament reconstruction: A longitudinal study.* Clin Biomech (Bristol, Avon), 2016. **32**: p. 249-54.

24. Filbay, S.R., K.M. Crossley, and I.N. Ackerman, *Activity preferences, lifestyle modifications and re-injury fears influence longer-term quality of life in people with knee symptoms following anterior cruciate ligament reconstruction: a qualitative study.* J Physiother, 2016. **62**(2): p. 103-10.
25. Scott, S.M., M.A. Perry, and G. Sole, *"Not always a straight path": patients' perspectives following anterior cruciate ligament rupture and reconstruction.* Disabil Rehabil, 2017: p. 1-7.
26. Culvenor, A.G. and C.J. Barton, *ACL injuries: the secret probably lies in optimising rehabilitation.* Br J Sports Med, 2018: p. bjsports-2017-098872.
27. Clark, N.C., *(vii) The role of physiotherapy in rehabilitation of soft tissue injuries of the knee.* Orthopaedics and Trauma, 2015. **29**(1): p. 48-56.
28. Krishnasamy, P., M. Hall, and S.R. Robbins, *The role of skeletal muscle in the pathophysiology and management of knee osteoarthritis.* Rheumatology, 2018. **57**(suppl_4): p. iv22-iv33.
29. Palmieri-Smith, R.M., A.C. Thomas, and E.M. Wojtys, *Maximizing quadriceps strength after ACL reconstruction.* Clin Sports Med, 2008. **27**(3): p. 405-24, vii-ix.
30. Turner, C.H. and A.G. Robling, *Designing exercise regimens to increase bone strength.* Exerc Sport Sci Rev, 2003. **31**(1): p. 45-50.
31. Flosadottir, V., E.M. Roos, and E. Ageberg, *Muscle function is associated with future patient-reported outcomes in young adults with ACL injury.* BMJ Open Sport Exerc Med, 2016. **2**(1): p. e000154.
32. Schmitt, L.C., M.V. Paterno, and T.E. Hewett, *The impact of quadriceps femoris strength asymmetry on functional performance at return to sport following anterior cruciate ligament reconstruction.* J Orthop Sports Phys Ther, 2012. **42**(9): p. 750-9.
33. Bodkin, S., et al., *Relationships of Muscle Function and Subjective Knee Function in Patients After ACL Reconstruction.* Orthop J Sports Med, 2017. **5**(7): p. 2325967117719041.
34. Lentz, T.A., et al., *Return to preinjury sports participation following anterior cruciate ligament reconstruction: contributions of demographic, knee impairment, and self-report measures.* J Orthop Sports Phys Ther, 2012. **42**(11): p. 893-901.
35. Williams, G.N., et al., *Quadriceps weakness, atrophy, and activation failure in predicted noncopers after anterior cruciate ligament injury.* The American journal of sports medicine, 2005. **33**(3): p. 402-407.
36. Augustsson, J., *Documentation of strength training for research purposes after ACL reconstruction.* Knee Surg Sports Traumatol Arthrosc, 2013. **21**(8): p. 1849-55.
37. Toigo, M. and U. Boutellier, *New fundamental resistance exercise determinants of molecular and cellular muscle adaptations.* Eur J Appl Physiol, 2006. **97**(6): p. 643-63.
38. Spiering, B.A., et al., *Resistance exercise biology: manipulation of resistance exercise programme variables determines the responses of cellular and molecular signalling pathways.* Sports Med, 2008. **38**(7): p. 527-40.
39. Simao, R., et al., *Exercise order in resistance training.* Sports Med, 2012. **42**(3): p. 251-65.
40. Kraemer, W.J., Koziris, L.P., *Muscle Strength Training: Techniques and Considerations.* Physical Therapy Practice, 1992. **2**(1): p. 54-68.
41. Morrissey, M.C., E.A. Harman, and M.J. Johnson, *Resistance training modes: specificity and effectiveness.* Medicine and science in sports and exercise, 1995. **27**(5): p. 648-660.
42. Lepley, L.K., E.M. Wojtys, and R.M. Palmieri-Smith, *Combination of eccentric exercise and neuromuscular electrical stimulation to improve quadriceps function post-ACL reconstruction.* Knee, 2015. **22**(3): p. 270-7.
43. Sievanen, H., et al., *Bone mineral density and muscle strength of lower extremities after long-term strength training, subsequent knee ligament injury and rehabilitation: a unique 2-year follow-up of a 26-year-old female student.* Bone, 1994. **15**(1): p. 85-90.
44. Barcellona, M., et al., *The effect of knee extensor open kinetic chain resistance training in the ACL-injured knee.* Knee Surgery, Sports Traumatology, Arthroscopy, 2015. **23**(11): p. 3168-3177.
45. Thomas, M., T. Müller, and M. Busse, *Quantification of tension in Thera-Band and Cando tubing at different strains and starting lengths.* J Sports Med Phys Fitness, 2005. **45**(2): p. 188-198.
46. Simoneau, G., et al., *Biomechanics of elastic resistance in therapeutic exercise programs.* J Orthop Sports Phys Ther, 2001. **31**(1): p. 16-24.
47. Webster, K.E., et al., *Symmetry of squatting and the effect of fatigue following anterior cruciate ligament reconstruction.* Knee Surg Sports Traumatol Arthrosc, 2015. **23**(11): p. 3208-13.

48. Goff, A., W. Page, and N. Clark, *Reporting of acute programme variables in rehabilitation strength training for anterior cruciate ligament injury: a systematic review.* Br J Sports Med, 2017. **51 (Suppl 2)**: p. A6-A7.
49. Slade, S.C., et al., *Consensus on Exercise Reporting Template (CERT): Modified Delphi Study.* Phys Ther, 2016. **96**(10): p. 1514-1524.
50. Holden, S., et al., *How can we implement exercise therapy for patellofemoral pain if we don't know what was prescribed? A systematic review.* Br J Sports Med, 2017. **52**(6): p. 1-8.
51. PROSPERO. Available from: https://www.crd.york.ac.uk/prospero/.
52. Liberati, A., et al., *The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration.* J Clin Epidemiol, 2009. **62**(10): p. e1-34.
53. Moher, D., et al., *Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement.* BMJ, 2009. **339**: p. b2535.
54. Havill, N.L., et al., *Managing Large-Volume Literature Searches in Research Synthesis Studies.* Nurs Outlook, 2014. **62**(2): p. 112-118.
55. CEBM. Available from: https://www.cebm.net/2014/04/study-designs/.
56. Koepsell, T.D., *Selecting a Study Design for Injury Research*, in *Injury control: a guide to research and program evaluation*, F.P.C. Rivara, P.; Koespell, T.D.; Grossman, D.C.; Maier, R.V., Editor. 2009, Cambridge University Press. p. 89-104.
57. Arundale, A.J.H., et al., *Report of the clinical and functional primary outcomes in men of the ACL-SPORTS trial: similar outcomes in men receiving secondary prevention with and without perturbation training 1 and 2 years after ACL reconstruction.* Clinical Orthopaedics and Related Research 2017 Oct;475(10):2523-2534, 2017.
58. Berschin, G., et al., *Whole Body Vibration Exercise Protocol versus a Standard Exercise Protocol after ACL Reconstruction: A Clinical Randomized Controlled Trial with Short Term Follow-Up.* Journal of Sports Science & Medicine, 2014. **13**(3): p. 580-589.
59. Bieler, T., et al., *The effects of high-intensity versus low-intensity resistance training on leg extensor power and recovery of knee function after ACL-reconstruction.* BioMed Research International 2014;(278512):Epub, 2014.
60. Hart, J.M., et al., *Quadriceps function in anterior cruciate ligament-deficient knees exercising with transcutaneous electrical nerve stimulation and cryotherapy: a randomized controlled study.* Clin Rehabil, 2012. **26**(11): p. 974-81.
61. Hartigan, E., *Knee function after ACL rupture and reconstruction effects of neuromuscular training*. 2009, University of Delaware. p. 200 p-200 p.
62. Holm, L., et al., *The effect of protein and carbohydrate supplementation on strength training outcome of rehabilitation in ACL patients.* J Orthop Res, 2006. **24**(11): p. 2114-23.
63. Kinikli, G.I., et al., *The effect of progressive eccentric and concentric training on functional performance after autogenous hamstring anterior cruciate ligament reconstruction: a randomized controlled study.* Acta Orthopaedica et Traumatologica Turcica 2014;48(3):283-289, 2014.
64. Pistone, E.M., et al., *Effects of early whole-body vibration treatment on knee neuromuscular function and postural control after anterior cruciate ligament reconstruction: a randomized controlled trial.* Journal of Rehabilitation Medicine 2016 Oct;48(10);880-886, 2016.
65. Risberg, M.A., et al., *Neuromuscular training versus strength training during first 6 months after anterior cruciate ligament reconstruction: a randomized clinical trial.* Physical Therapy 2007 Jun;87(6):737-750, 2007.
66. Risberg, M.A., et al., *Rehabilitation after anterior cruciate ligament injury influences joint loading during walking but not hopping.* Br J Sports Med, 2009. **43**(6): p. 423-8.
67. Sekir, U., H. Gur, and B. Akova, *Early versus late start of isokinetic hamstring-strengthening exercise after anterior cruciate ligament reconstruction with patellar tendon graft.* The American Journal of Sports Medicine 2010 Mar;38(3):492-500, 2010.
68. Souissi, S., et al., *Improving Functional Performance and Muscle Power 4-to-6 Months After Anterior Cruciate Ligament Reconstruction.* J Sports Sci Med, 2011. **10**(4): p. 655-64.
69. Ericsson, Y.B., L.E. Dahlberg, and E.M. Roos, *Effects of functional exercise training on performance and muscle strength after meniscectomy: a randomized trial.* Scand J Med Sci Sports, 2009. **19**(2): p. 156-65.

70. Morrissey, M.C. and P.C. Goodwin, *Correlates of knee extensor training load used in rehabilitation after knee surgery.* J Strength Cond Res, 2007. **21**(4): p. 1050-2.
71. Wondrasch, B., et al., *The feasibility of a 3-month active rehabilitation program for patients with knee full-thickness articular cartilage lesions: the Oslo Cartilage Active Rehabilitation and Education Study.* J Orthop Sports Phys Ther, 2013. **43**(5): p. 310-24.
72. Minshull, C. and N. Gleeson, *Considerations of the Principles of Resistance Training in Exercise Studies for the Management of Knee Osteoarthritis: A Systematic Review.* Arch Phys Med Rehabil, 2017. **98**(9): p. 1842-1851.
73. Button, K., et al., *Clinical effectiveness of knee rehabilitation techniques and implications for a self-care treatment model.* Physiotherapy, 2012. **98**(4): p. 287-299.
74. McMullen, W., A. Roncarati, and P. Koval, *Static and isokinetic treatments of chondromalacia patella: a comparative investigation.* Journal of Orthopaedic & Sports Physical Therapy, 1990. **12**(6): p. 256-266.
75. Babault, N., et al., *Neuromuscular fatigue development during maximal concentric and isometric knee extensions.* Journal of applied physiology, 2006. **100**(3): p. 780-785.
76. Kay, D., et al., *Different neuromuscular recruitment patterns during eccentric, concentric and isometric contractions.* Journal of Electromyography and Kinesiology, 2000. **10**(6): p. 425-431.
77. Howatson, G. and K.A. van Someren, *The prevention and treatment of exercise-induced muscle damage.* Sports Med, 2008. **38**(6): p. 483-503.
78. Rasch, P.J. and L.E. Morehouse, *Effect of static and dynamic exercises on muscular strength and hypertrophy.* Journal of Applied Physiology, 1957. **11**(1): p. 29-34.
79. Kraemer, W.J. and N.A. Ratamess, *Fundamentals of resistance training: progression and exercise prescription.* Med Sci Sports Exerc, 2004. **36**(4): p. 674-88.
80. Bruton, A., *Muscle plasticity: response to training and detraining.* Physiotherapy, 2002. **88**(7): p. 398-408.
81. Schoenfeld, B.J., *The mechanisms of muscle hypertrophy and their application to resistance training.* The Journal of Strength & Conditioning Research, 2010. **24**(10): p. 2857-2872.
82. Kraemer, W.J., *Strength training basics: designing workouts to meet patients' goals.* Phys Sportsmed, 2003. **31**(8): p. 39-45.
83. Haff, G.G., *Quantifying workloads in resistance training: a brief review.* Strength and Cond, 2010. **10**: p. 31-40.
84. Cronin, J., P. McNair, and R. Marshall, *Is velocity-specific strength training important in improving functional performance?* Journal of sports medicine and physical fitness, 2002. **42**(3): p. 267.
85. Pereira, M.I. and P.S. Gomes, *Movement velocity in resistance training.* Sports medicine, 2003. **33**(6): p. 427-438.
86. Bird, S.P., K.M. Tarpenning, and F.E. Marino, *Designing resistance training programmes to enhance muscular fitness.* Sports medicine, 2005. **35**(10): p. 841-851.
87. Hatfield, D.L., et al., *The impact of velocity of movement on performance factors in resistance exercise.* J Strength Cond Res, 2006. **20**(4): p. 760-6.
88. Burd, N.A., et al., *Muscle time under tension during resistance exercise stimulates differential muscle protein sub-fractional synthetic responses in men.* J Physiol, 2012. **590**(2): p. 351-62.
89. Tran, Q.T. and D. Docherty, *Dynamic training volume: a construct of both time under tension and volume load.* Journal of sports science & medicine, 2006. **5**(4): p. 707.
90. Gentil, P., E. Oliveira, and M. Bottaro, *Time under tension and blood lactate response during four different resistance training methods.* Journal of physiological anthropology, 2006. **25**(5): p. 339-344.
91. Barcellona, M.G., et al., *The effect of knee extensor open kinetic chain resistance training in the ACL-injured knee.* Knee Surg Sports Traumatol Arthrosc, 2015. **23**(11): p. 3168-77.
92. Lepley, L.K., *Deficits in quadriceps strength and patient-oriented outcomes at return to activity after ACL reconstruction: a review of the current literature.* Sports health, 2015. **7**(3): p. 231-238.
93. van Grinsven, S., et al., *Evidence-based rehabilitation following anterior cruciate ligament reconstruction.* Knee Surgery, Sports Traumatology, Arthroscopy 2010 Aug;18(8):1128-1244, 2010.
94. Grgic, J., et al., *The effects of short versus long inter-set rest intervals in resistance training on measures of muscle hypertrophy: A systematic review.* Eur J Sport Sci, 2017. **17**(8): p. 983-993.

95. McKendry, J., et al., *Short inter-set rest blunts resistance exercise-induced increases in myofibrillar protein synthesis and intracellular signalling in young males.* Exp Physiol, 2016. **101**(7): p. 866-82.
96. Dankel, S.J., et al., *Frequency: The Overlooked Resistance Training Variable for Inducing Muscle Hypertrophy?* Sports Med, 2017. **47**(5): p. 799-805.
97. Dye, S., *The knee as a biologic transmission with an envelope of function: a theory.* Clin Orthop Relat Res, 1996(325): p. 10-18.
98. Sanford, B.A., et al., *Asymmetric ground reaction forces and knee kinematics during squat after anterior cruciate ligament (ACL) reconstruction.* Knee, 2016. **23**(5): p. 820-5.
99. Trulsson, A., et al., *Altered movement patterns and muscular activity during single and double leg squats in individuals with anterior cruciate ligament injury.* BMC Musculoskelet Disord, 2015. **16**: p. 28.
100. Toutoungi, D., et al., *Cruciate ligament forces in the human knee during rehabilitation exercises.* Clinical biomechanics, 2000. **15**(3): p. 176-187.
101. Davies, G.J., et al., *ACL Return to Sport Guidelines and Criteria.* Curr Rev Musculoskelet Med, 2017. **10**(3): p. 307-314.
102. Adams, D., et al., *Current concepts for anterior cruciate ligament reconstruction: a criterion-based rehabilitation progression.* journal of orthopaedic & sports physical therapy, 2012. **42**(7): p. 601-614.
103. Hoffmann, T.C., et al., *Better reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide.* BMJ, 2014. **348**: p. g1687.

Highlights

- Many acute programme variables were not adequately reported for ACL studies
- Many exercise descriptors were not adequately reported for ACL studies
- Most acute programme variables were not adequately reported for meniscus studies
- Many exercise descriptors were not adequately reported for meniscus studies

Ethical statement:

Ethical approval not required. None declared

Funding:

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors